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RESEARCH ARTICLE

Some rare plant species in the Aktolagay cretaceous massif (Republic of Kazakhstan): the characteristics of populations

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Abstract

Cretaceous massifs of the Eurasian continent are unique not only for their geological features but also for the peculiar flora. Therefore, the identification and study of the biodiversity of these unique objects is currently an actual task. Comprehensive studies of the flora and vegetation of the Aktolagay cretaceous massif (Republic of Kazakhstan) were carried out in 2019. One of the study aspects was the consideration of the ecological and biological features of several plant species typical for this territory. The research is devoted to the study of five plant species: *Astragalus lasiophyllus* Ledeb., *Astragalus vulpinus* Willd., *Matthiola tatarica* (Pall.) DC., *Eremurus inderiensis* (M. Bieb.) Regel, *Tragopogon ruber* S.G. Gmel. The coenopopulations (CP) of the species are located in the lower parts of the slopes, as well as in aligned areas at the foot on cretaceous substrates, and on sandstone soils. The total density of the studied CPs varies from 2.2 to 6.6 ind./m^2, the effective density varies from 1.6 to 4.9 ind./m^2. The studied coenopopulations belong to normal incomplete ones. The most typical feature is the absence of seedlings, juvenile and senile individuals in the spectrum, while the peak falls on mature generative individuals, in the *Mattiolla tatarica* coenopopulations – on virginile individuals. Coenopopulations differ in their type ("delta-omega" criterion): the *Matthiola tatarica* one is young, the CP of *Astragalus lasiophyllus* is transitional, the CPs of *Astragalus vulpinus* and *Eremurus inderiensis* are maturing, and

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the CP of *Tragogon ruber* is mature. The recruitment index is high in the CP of *Matthiola tatarica* (3.05), in the rest of the CPs it is not higher than one (0.36-0.82), the ageing index is equal or close to zero (0.00–0.10). Most morphometric features show the low levels of variability and plasticity.

Keywords
Aktolagai cretaceous massif, Republic of Kazakhstan, species on the edge of the range, rare species, coenopulation, ontogenetic structure, morphometric parameters, variability

Introduction

Cretaceous hills are the unique natural formations of the Eurasian continent, characterized by the high endemism and wide variety of relict plant species due to extreme ecological living conditions (Darbaeva 2003, 2006; Golovanov and Abramova 2019). This makes these territories an important object of study and protection at the regional and global levels (Matyashenko 1985; Darbaeva 2003). Currently, the vegetation cover of many cretaceous massifs in the Republic of Kazakhstan (RK) is not adequately secured by the environmental protection measures. For example, the Aktolagay cretaceous plateau (the Southern Aktolagay plateau) is in the list of geological, geomorphological and hydrogeological objects of the state nature reserve fund of the republican and international significance (List... 2010). However, this territory is unique not only for its geological features but also for the peculiar flora, therefore, the identification and study of the biodiversity of these unique objects is currently an urgent task.

The research is devoted to the study of five plant species from this territory: *Astragalus lasiophyllus* Ledeb., *Astragalus vulpinus* Willd., *Matthiola tatarica* (Pall.) DC., *Eremurus inderiensis* (M. Bieb.) Regel, *Tragopogon ruber* S.G. Gmel. For all the considered species, the territory of the Russian Federation is the most northern distribution area, and two species *Astragalus lasiophyllus* and *A. vulpinus* are included in the regional Red Data Books (Red Data Book of Stavropol Krai 2002; Red Data Book of Saratov Oblast 2006; Red Data Book of the Republic of Kalmykia 2014; Red Data Book of Orenburg Oblast 2019). The biology, structure, and state of these species' populations, located within their main range in the territory of both the Aktolagay cretaceous massif and Northwest Kazakhstan, have not been previously studied.

The purpose of the research was to study the ecological and biological characteristics, structure, and condition of the coenopopulations of some plant species characteristic for the territory of the Aktolagay cretaceous massif. The objectives included the identification of demographic indicators, the distribution of CP by the types of ontogenetic spectra, and the study of morphometric parameters. The identification of the enlisted characteristics of the species within their main range will make it possible to understand the reasons for their rarity and/or to organize their appropriate protection in various regions of the Russian Federation.

Material and methods

Comprehensive studies of the flora and vegetation of the Aktolagay cretaceous massif were carried out in 2019. One of the aspects was the consideration of the ecological and biological characteristics of several plant species in this territory.

The Aktolagay cretaceous massif (Figs 1, 2) (47.518414°N; 55.119016°E) is located in the Bayganin district of the Aktobe Region, the Republic of Kazakhstan, which adjoins the Caspian Depression along the Emba river. The ridge is 90 km long, 5–10 km wide, the highest peak is Kiyakty (217 m). The elevation difference on the plateau scarp reaches more than 130 m, the western slope is steep, dissected by ravines and gullies. The vegetation cover is represented by various types of calciphytic communities developing on chalky rocks, as well as *Artemisia terrae-albae*, *Atriplex cana* and *Anabasis salsa* coenoses, observed in upland habitats and characteristic for the northern deserts of Central Asia. In crevices and on shaded slopes, there are shrub communities with dominated *Atraphaxis* L. genus. To the west of the ridge, there is a dried Tolagaysor lake (Ayagan 2004). The anthropogenic load is insignificant due to the low population density in the area. Previously, there was an active grazing at the foot of the ridge, now it has decreased significantly. This territory is located within the natural zone of northern deserts with the low precipitation of 150–200 mm (Hydrothermal coefficient = 0.3). The accumulated air temperatures above +10C is equal to 3600C. The soils in the highlands are mostly brown (Agroclimatic resources ... 2017).

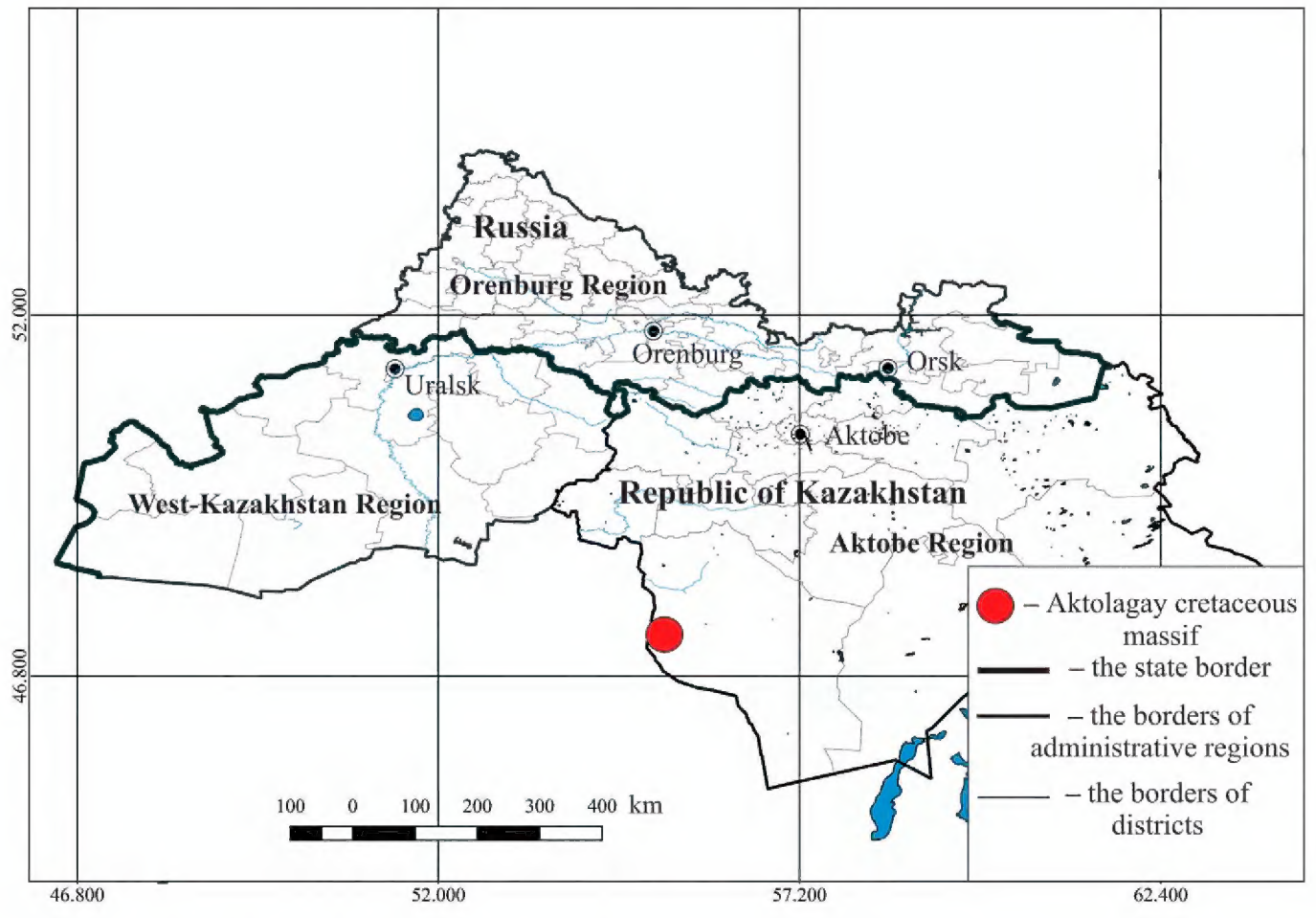


Figure 1. Location of the Aktolagay cretaceous massif on the map.

Figure 2. View from the slope of Aktolagay cretaceous massif.

Below is a brief description of the species found both in the Cretaceous outcrops and in the foothills of relatively flat habitats. Species names are given in accordance with the database "The Plant List" (2013).

Astragalus lasiophyllus (Fabaceae family) (Fig. 3) is a perennial plant of 5–10 cm tall, stemless or with short stems. The leaves are ovate, the upper leaves are ovate-lanceolate, whitish. Leaflets 4–7 are paired, oblong-oval. Peduncles are densely white-haired, racemes are shortened, the corolla is lavender; the banner is oblong-obovate, the keel is wide, slightly curved, and obtuse. The pods have a short pedicle, are rounded, ovoid, and biloculate. Flowering occurs in April-May, and fructification occurs in May-June. It grows in wormwood and saltwort-wormwood, as well as in sandy steppes, at chalk and tertiary clay outcrops. It was recorded in Central Asia, Mongolia. In the Republic of Kazakhstan, it can be encountered in its north-western and western parts, as well as in the Balkhash region, Dzhungarian, Trans-Ili and Kungey Alatau, Chu-Ili mountains, Karatau (Komarov, Shishkin 1946).

Astragalus vulpinus (Fabaceae family) (Fig. 4) is a perennial 30–100 cm tall plant. The stem is straight, pubescent or almost glabrous. The leaves are broadly ovate or obcordate, puberulent on the lower leaf surface, and almost glabrous on the upper side. Flowers are sessile, the corolla is yellowish, the banner is equal to or slightly longer than the wings and the keel, oblong-obovate, the keel is angular, obtuse. The pod is oval, densely covered with white hairs. It grows in sandy and clay steppes, on sandy shores, in solonetz and rocky places, meadows. The range of the species covers the Lower Volga and the Transvolga region, Western Siberia,

Central Asia, and is widely distributed in the territory of the Republic of Kazakhstan (Komarov, Shishkin 1946).

Matthiola tatarica (Brassicaceae family) (Fig. 5) is a perennial 25–50 (100) cm tall plant. The stem is straight, glabrous, sometimes pubescent in the lower part. The leaves are large, from sinuate-dentate to pinnatipartite, densely pubescent, green, the lower ones are oblong. Flowers are yellowish or slightly purple. The pods are glabrous. It settles mainly on chalk slopes and on steppes. It is found in the European part of the Russian Federation in the Lower Volga region, in Western Siberia and Central Asia. In the Republic of Kazakhstan, it is distributed mainly in the Western part (the Aral Sea region, the Ustyurt, the Caspian Sea region) (Chernyakovskaya 1939).

Eremurus inderiensis (Asphodelaceae family) is a perennial plant, 80–130 cm tall, with fusiform thickened roots and a straight, puberulent or glabrous, thick stem. The leaves are linear, smooth, or scabrous. The raceme is cylindrical, rather thick. The perianth is cylindrical- campanulate, dirty purple, each lobe has a wide green stripe and three veins. The capsule is rounded, slightly flattened, glabrous. The seeds are broadly winged, and triquetrous. Flowering occurs in May-June. It grows in sandy deserts and semi-deserts. The species range covers Central Asia, Dzhungaria, Iran, Afghanistan, and Mongolia. It is widely spread in the Republic of Kazakhstan (Fedchenko 1935).

Figure 3. *Astragalus lasiophyllus* Ledeb.

Tragopogon ruber (Asteraceae family) (Fig. 6) is a perennial plant, up to 30 cm tall. The root is vertical and vigorous. Stems are glaucous gray-green, branched below, glabrous. The middle leaves are widened at the base, semi-amplexicaul, lanceolate-linear. When bearing fruit, capitula are large. The flowers are pink-purple. The species blooms in April-May, bears fruit in June. It grows on sands and terraces above the flood-plains, gentle and rocky slopes, along the steppe alluvial benches. The range covers the southeast of the former USSR European part, Western China. It is widely spread in the Republic of Kazakhstan (Borisova 1964).

In order to assess the phytocoenotic confinement of coenopopulations, we carried out a geobotanical relevés of the community using traditional geobotanical methods on the plots of 100 m^2, strip- or square-shaped, for each CP (Mirkin and Rosenberg 1978).

To study the demographic structure and density of CP, 25 test plots, 1 m^2 in size, were established on the transect in each of them. The order of establishment (line or belt) and the transect step (5 or 10 m) depended on the area occupied by a particular coenopopulation. The main population characteristics were identified: total and effective density, age composition. The age pattern of CP was determined by standard methods (Rabotnov 1950, Uranov 1975, Coenopopulations ... 1976), the following age states were considered: juvenile (j), immature (im), virginile (v), young generative (g1), mature generative (g2), old generative (g3), sub-senile (ss), senile (s). On the basis of the data obtained, the ontogenetic (age) spectra of CP were constructed.

Figure 4. *Astragalus vulpinus* Willd.

Figure 5. *Matthiola tatarica* (Pall.) DC.

To characterize the ontogenetic structure of CP, the generally accepted demographic indicators were used: recruitment index (Zhukova 1995), ageing index (Glotov 1998). For assessing the state of CP, we applied the "delta-omega" criterion by L.A. Zhivotovsky (Zhivotovsky 2001) based on the combined use of the age (Δ) (Uranov 1975) and efficiency (ω) (Zhivotovsky 2001) indices. The study of morphometric parameters in vivo was carried out according to the method of V.N. Golubev (1962) on 25 generative plants of each CP. The calculation of the index of phytocoenotic plasticity (I_p) of studied characters was conducted using the method of Yu.A. Zobnin (1989). When analyzing quantitative indicators, standard procedures were used: M arithmetic means, errors of the M arithmetic mean, coefficient of variation C_v (%) (Zaitsev 1990).

Figure 6. *Tragopogon ruber* S.G. Gmel.

Results and discussion

The coenopopulations of the studied species are located in the lower parts of the slopes, as well as in the leveled areas at the foot on chalk substrates and on sandy soils. Coenopopulations of *Astragalus lasiophyllus* and *Matthiola tatarica* were observed almost only in the flattened areas at the base of the chalk cliffs. The grass stand is very sparse, the projective cover is 20–30 %. The average height of the herbage is low and ranges from 5 to 15 cm. The communities mostly have a low species diversity and include 11–18 species per plot. An important role in the composition of the communities belongs to the dwarf-shrubs characteristic of the chalk out-

crops of Northwestern Kazakhstan (*Anabasis cretacea*, *Lepidium meyeri*, *Limonium suffruticosum* (L.) Kuntze, *Nanophyton erinaceum* (Pall.) Bunge, *Silene fruticulosa* M.Bieb. and others) and the surrounding areas of zonal vegetation (*Anabasis salsa* (Ledeb.) Benth.ex Volkens, *Atriplex cana* Ledeb., *Artemisia terrae-albae* Krasch., *Convolvulus fruticosus* Pall., etc.).

Coenopopulations of *Astragalus vulpinus*, *Eremurus inderiensis*, and *Tragopogon ruber* were confined to the leveled areas with sandy soils within the zonal plant aggregations dominated by *Artemisia terrae-albae* and featuring *Anabasis aphylla* L. The projective cover of the grass stand is 45 to 50 %, the average height ranges from 25 to 30 cm. The species diversity of the communities is low and reaches 18–22 species per plot. The communities are characterized by a high proportion of annuals typical for desert communities (*Bromus tectorum* L., *Eremopyrum distans* (K.Koch) Nevski, *Lappula spinocarpos* (Forssk.) Asch. ex Kuntze, *Nonea caspica* (Willd.) G.Don, etc.).

The contribution of plants at different age states to the population density is evaluated by their energy efficiency (Zhivotovsky 2001). The total effective density, age composition, and demographic structure of the coenopopulations of the studied species are presented in Table 1.

Table 1. Distribution of individuals by ontogenetic group and demographic indicators in cenopopulations

Cenopopulation		***Mattiolla tatarica***	***Astragalus lasiophyllus***	***Eremurus inderiensis***	***Astragalus vulpinus***	***Tragopogon ruber***
Effective density, ind./m^2		3.0	3.1	4.9	1.6	2.7
Density, ind./m2		6.6	4.5	7.8	2.2	3.7
Ontogenetic state, %	j	0	0.9	11.2	1.8	0
	im	9.0	4.5	15.8	8.9	5.4
	v	23.5	32.1	16.8	26.8	18.5
	g_1	42.8	10.7	6.1	14.3	18.5
	g_2	6.0	32.1	41.8	44.6	37.0
	g_3	15.7	15.2	5.6	3.6	10.9
	ss	3.0	4.5	2.6	0	7.6
	s	0	–	–	–	2.2
Demographic indicators	Δ	0.18	0.38	0.32	0.32	0.43
	ω	0.46	0.69	0.63	0.72	0.72
	CPs Type	young	transitional	maturing	maturing	mature
	I_B	3.05	0.65	0.82	0.60	0.36
	I_{CT}	0.00	0.04	0.03	0.00	0.10

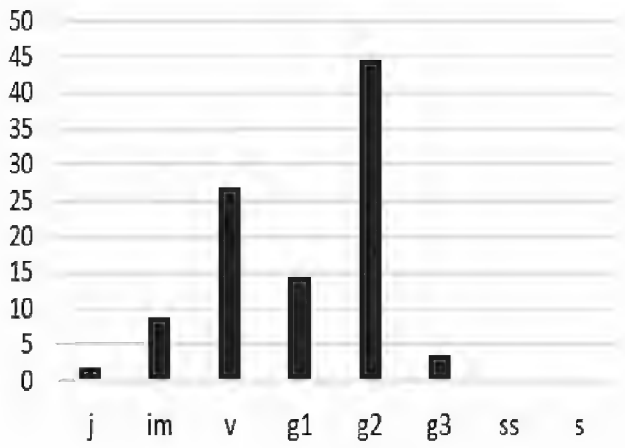
The total density of the studied CPs varies from 2.2 to 6.6 ind./m^2, the effective density varies from 1.6 to 4.9 ind./m^2. The maximum density is noted in the CP of *E. inderiensis*, the minimum accounts for the CP of *A. vulpinus*. Almost all coenopopulations are dominated by the generative fraction. There are significantly more generative plants in the *A. vulpinus* CP (20.8 %), where the values of the total and effective density are minimal (1.6 and 2.2 ind./m^2). The pre-generative fraction is maximal in the CP of *E. inderiensis* (14.6 %), where the difference in density indices is the most pronounced. The largest number of post-generative individuals was recorded in the *T. ruber* CP (4.9 %).

The coenopopulations of the studied species are characterized by a clear identification of various ontogenetic states. The ontogenetic structure of CP is influenced by the ecological conditions of habitation, such as insufficient moisture, relief features, and fluctuations in weather conditions. Bayganin District of the Republic of Kazakhstan, where the Aktolagay mountain range is located, is characterized by a very dry continental climate with insufficient moistening, which has a significant impact on the formation of the coenopopulation structure, on the patterns of seed germination, and the development rate of individuals in a particular ontogenetic state. The precipitation shortage does not allow seeds to germinate well and can lead to the death of seedlings. The complex ecological conditions of the biotopes of the cretaceous mountains, characterized by specific microclimatic and edaphic conditions, lead to the absence of individual ontogenetic states in coenopopulations, for example, juveniles in the *T. ruber* CP and the absence of seedlings, sub-senile and senile individuals in the spectra of most CPs. As a result of these processes, coenopopulations of the studied species generally have an incomplete structure (Fig. 7).

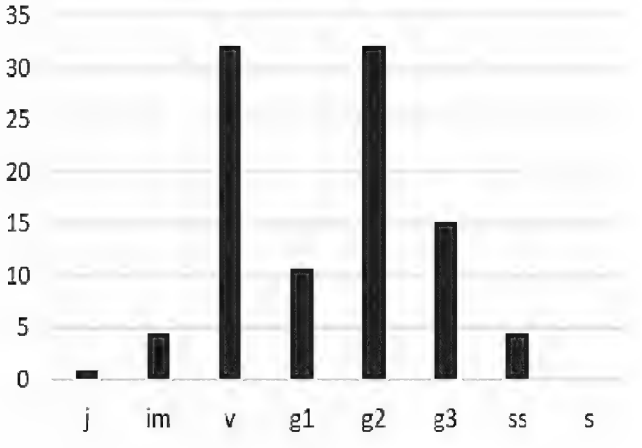
A. vulpinus, *E. inderiensis*, and *T. ruber* develop a centered spectrum. The absolute maximum falls on mature generative individuals (37.0–44.6 %). In the CP of *A. vulpinus*, a second, lower peak is observed in virginal individuals. The pre-generative fraction in all CPs of the studied species is well represented; only *T. ruber* lacks juveniles. Drying out of the substrate in hot seasons leads to the death of young plants and contributes to the loss of these stages. The representation of the post-generative fraction is low; it is completely absent in *A. lasiophyllus* and *M. tatarica*. In *A. vulpinus* and *E. inderiensis* only sub-senile individuals were recorded; in the CP of *T. ruber* this fraction is fully represented.

The coenopopulations of *A. lasiophyllus* form a spectrum with two peaks – on virginal and middle-aged generative individuals (32.1% each). This type of spectrum is formed in populations with the growing conditions favorable for both the pre-generative and generative fractions. This is due to the fact that most of the individuals die off in the old generative or sub-senile state.

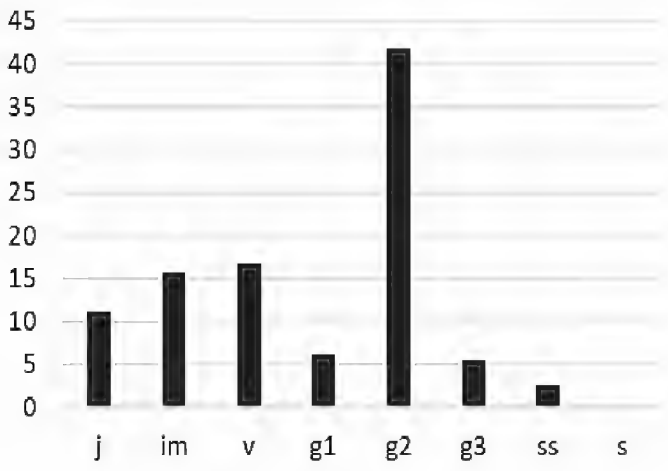
In the CP of *M. tatarica*, a left-sided spectrum is formed. The peak falls on virginile individuals (42.8%). Coenopopulations of the species are located in upland habitats with a low grass stand density, where the processes of chalk rocks erosion are not so intense, which allows seeds to germinate and young individuals to develop.



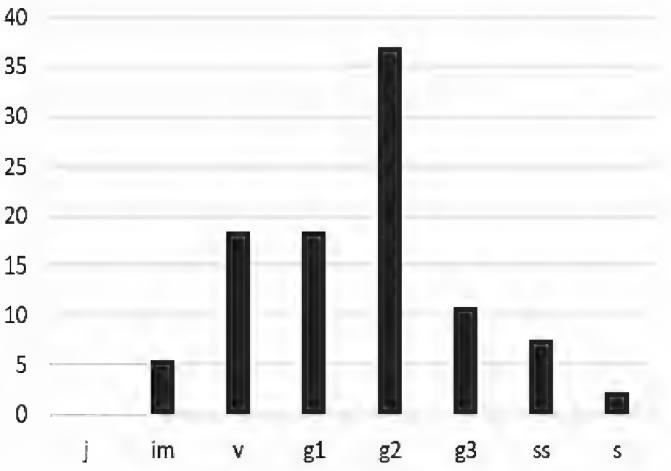
Astragalus vulpinus



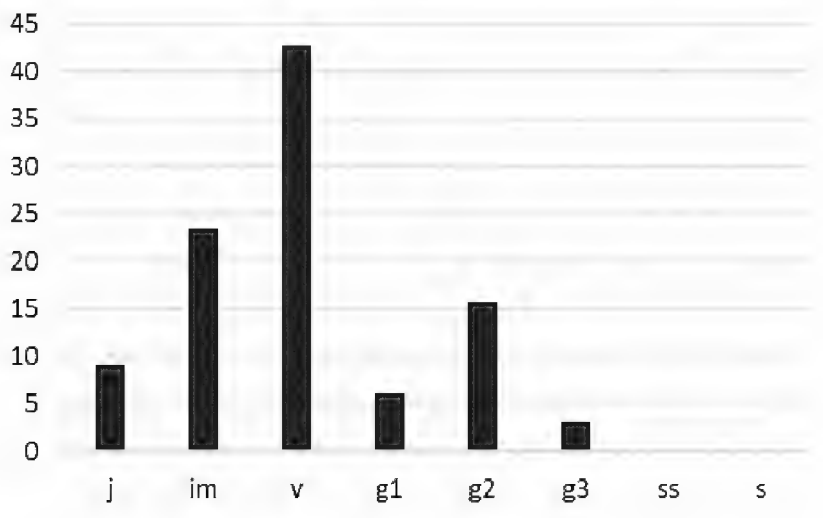
Astragalus lasiophyllus



Eremurus inderiensis



Tragopogon ruber



Mattiolla tatarica

Figure 7. Ontogenetic spectrum. On the abscissa axis – the ontogenetic state; on the ordinate axis – the proportion of individuals of this ontogenetic state, %.

In almost all species, a decrease in individuals of the young generative state is observed, which may be associated with their short stay during this period, and, conversely, with a rather long preparation of the species for the first flowering, which increases the duration of the virginal ontogenetic state. The exception is *T. ruber*, which apparently is associated with the greater resistance of the pre-generative fraction of this species to difficult habitat conditions.

The analysis of age Δ (delta) and efficiency ω (omega) showed (Table 1) that coenopopulations are heterogeneous in their type. The CP of *M. tatarica* is young (Δ = 0.18, ω = 0.46). The CP of *A. lasiophyllus* is of the transitional type (Δ = 0.38, ω = 0.69), where the ratio of the pre-generative and generative fractions is close. CPs of *E. inderiensis* and *A. vulpinus* are characterized as maturing (Δ = 0.32, ω = 0.63 and Δ = 0.32, ω = 0.72), due to the accumulation of young and mature generative individuals. The CP of *T. ruber* is mature (Δ = 0.43, ω = 0.72), where the share of mature generative and post-generative plants is significant. The recruitment index (I_r) in the populations under consideration is quite high (0.36–3.05), which indicates a good replenishment of CPs by young individuals. In all CPUs, the ageing index is equal to or close to zero (0–0.10).

The ability to modify growth and morphogenetic processes in plants is one of the main mechanisms of adjustment to the ecological-phytocoenotic environment and the impact of various stress factors (Zlobin et al. 2013). Such modifications can be analyzed by calculating the coefficient of variation and the index of phytocoenotic plasticity of the studied characters. The characteristics of the morphometric parameters of the species under consideration are presented in Table 2.

The studies showed that on the coefficient of variation scale, most characters have a normal degree of variation. A high variation (69.0 %) is noted for the number of fruits in *A. lasiophyllus*, significant variation accounts for the number of generative shoots in *A. vulpinus* (58.9 %), for the number of generative shoots (46.1 %), branching (45.9 %), and number of pods per one generative shoot (47.9 %) in *M. tatarica*. A series of quantitative parameters have the highest phytocoenotic plasticity: the number of generative shoots, branches, fruits, and pods per shoot, as well as the length of inflorescence. Most of the characters have a low index. In the CP of *A. lasiophyllus*, the highest level of plasticity was found for the number of fruits and seeds per one generative shoot (I_p – 0.93 and 0.69, respectively). The plasticity index of other characters ranges from 0.20 to 0.50. In the CP of *A. vulpinus*, the indicators of the generative sphere are variable: the number of generative shoots and flowers, the length of generative shoots (I_p – 0.70–0.85). The plasticity index of the characters ranges from 0.34 to 0.66. In the CP of *E. inderiensis*, the indices of phytocoenotic plasticity are rather low (I_p – 0.26–0.58), what indicates a strong susceptibility to any external influences, and a weak response. The assessment of the *T. ruber* CP plasticity demonstrated that the greatest variability accounts for the number of generative shoots, as well as for the number and length of leaves, while the lowest accounts for the diameter of the flower. In the CP of *M. tatarica*, most characters have high plasticity indices (I_p – 0.72–0.86), therefore, plants adapt better to environmental

changes. We revealed that quantitative characters are more variable than metric ones. This picture corresponds to their biological nature: plants quickly respond to any external influences and respond flexibly to them by increasing or decreasing the number of shoots, flowers, and fruits, etc. Apparently, this allows plants to maintain an optimal morphological structure and optimal functioning.

In general, we can say that the ability of plant individuals for pronounced variability and plasticity constitutes their defensive tactics against unfavorable factors, serving as a tool for a fine adaptation to the environment.

Table 2. Intrapopulation variability of morphometric parameters

Morphometric parameters	Average values			Min–Max	I_p
	M	±m	C_V, %		
Astragalus lasiophyllus					
Generative shoot height, cm	5.5	0.84	15.3	4.2–7.5	0.44
The number of leaflets, pcs.	12.4	1.80	14.6	9.0–15.0	0.40
Leaf length, cm	4.5	0.51	11.3	3.8–5.5	0.30
Leaf width, cm	1.4	0.21	15.1	1.1–1.8	0.38
Leaflet length, cm	0.7	0.05	8.1	0.6–0.8	0.25
Leaflet width, cm	0.2	0.05	22.1	0.2–0.4	0.50
The number of fruits per shoot, pcs.	6.5	4.50	69.0	1.0–15.0	0.93
Fruit length, cm	2.1	0.20	9.5	1.7–2.5	0.32
Fruit width, cm	1.4	0.13	9.0	1.0–1.7	0.41
Bush diameter, cm	13.6	1.82	13.4	10.2–17.8	0.42
Astragalus vulpinus					
The number of generative shoots, pcs.	2.4	0.28	58.9	1.0–7.0	0.85
Generative shoot height, cm	29.9	1.80	20.8	11.2–49.0	0.77
Generative shoot diameter, cm	0.4	0.02	20.8	0.2–0.6	0.66
The number of leaves, pcs.	7.2	0.25	17.5	5.0–10.0	0.50
Leaf length, cm	23.6	0.90	18.7	18.5–33.5	0.44
Leaf width, cm	4.9	0.18	17.9	3.4–6.5	0.47
The number of leaflets, pcs.	28.0	0.71	12.7	23.0–35.0	0.34
Leaflet length, cm	2.4	0.08	17.4	1.6–3.0	0.46
Leaflet width, cm	1.5	0.05	16.4	1.0–2.2	0.54
The number of flowers per shoot, pcs.	23.6	1.23	1.1	10.0–34.0	0.70
Flower length, cm	2.5	0.04	0.0	2.0–3.0	0.33
Flower width, cm	1.6	0.03	10.3	1.2–2.0	0.40
The number of inflorescences per shoot, pcs.	3.4	0.18	26.9	2.0–5.0	0.60
Inflorescence length, cm	5.8	0.27	23.1	2.8–7.7	0.63

Morphometric parameters	Average values			Min–Max	I_p
	M	±m	C_V, %		
Inflorescence width, cm	4.1	0.10	11.8	3.5–5.4	0.35
Eremurus inderiensis					
Generative shoot height, cm	50.5	1.88	18.6	38.0–89.8	0.57
Generative shoot diameter, cm	1.0	0.04	18.5	0.8–1.4	0.42
The number of leaves, pcs.	12.8	0.28	11.1	11.0–15.0	0.26
Leaf length, cm	27.9	0.84	15.0	20.5–37.2	0.44
Leaf width, cm	1.6	0.07	20.6	1.0–2.4	0.58
Inflorescence length, cm	28.2	1.02	18.2	19.6–43.5	0.54
The number of flowers per shoot, pcs.	95.4	4.57	23.9	62.0–143.0	0.56
Flower length, cm	1.3	0.02	0.00	1.1–1.5	0.26
Tragopogon ruber					
The number of generative shoots, pcs.	1.7	0.15	44.5	1.0–4.0	0.75
Generative shoot height, cm	35.3	1.25	17.7	23.5–44.8	0.47
Generative shoot diameter, cm	0.4	0.01	14.4	0.3–0.5	0.40
The number of leaves per generative shoot, pcs.	25.1	1.46	29.0	14.0–47.0	0.70
Leaf length, cm	11.2	0.75	33.7	5.0–19.2	0.73
Leaf width, cm	2.4	0.13	26.3	1.2–3.4	0.64
The number of flowers per shoot, pcs.	4.2	0.26	30.8	2.0–6.0	0.66
Flower diameter, cm	5.3	0.10	9.3	4.4–6.5	0.32
Mattiolla tatarica					
The number of generative shoots, pcs.	1.4	0.13	46.1	3.0–1.0	0.67
Generative shoot height, cm	28.2	1.13	20.0	40.0–17.4	0.57
Generative shoot diameter, cm	0.4	0.01	18.2	0.5–0.3	0.50
The number of branches, pcs.	2.8	0.25	45.9	7.0–1.0	0.86
The number of leaves, pcs.	16.6	1.42	42.7	31.0–8.0	0.74
Leaf length, cm	4.3	0.18	21.2	6.2–3.0	0.52
Leaf width, cm	1.4	0.08	28.2	2.6–1.0	0.62
Inflorescence length, cm	16.2	1.23	37.8	27.8–5.5	0.80
The number of flowers per shoot, pcs.	10.8	0.72	0.7	18.0–5.0	0.72
Flower length, cm	1.5	0.02	0.0	1.7–1.4	0.18
Flower width, cm	2.1	0.07	16.6	2.8–1.2	0.57
The number of pods per shoot, pcs.	8.6	0.82	47.9	19.0–3.0	0.84
Pod length, cm	6.6	0.33	25.0	9.2–3.7	0.60

Conclusion

Based on the study results of the biological characteristics of 5 plant species in the Aktolagay cretaceous massif (*Astragalus lasiophyllus*, *Astragalus vulpinus*, *Matthiola tatarica*, *Eremurus inderiensis*, *Tragopogon ruber*), an analysis of the current state of their populations was carried out for the first time. The predominant type of vegetation, which includes the studied species, encompasses specific communities of northern calciphytic deserts with domination of dwarf shrubs of a xerophilic type, as well as coenoses of zonal steppes on sandy light substrates. The studied CPs belong to normal incomplete ones. The most typical feature is the absence of seedlings, juvenile and senile individuals in the spectrum, while the peak falls on mature generative individuals, in the *Mattiolla tatarica* CP – on virginile individuals. The CP of *Astragalus lasiophyllus* has a spectrum with two peaks in virginile and mature generative individuals. Coenopopulations differ in their type: the *Matthiola tatarica* one is young, the CP of *Astragalus lasiophyllus* is transitional, the CPs of *E. inderiensis* and *A. vulpinus* are maturing, and the CP of *T. ruber* is mature. The recruitment index in the studied populations is rather high (0.36–3.05), the ageing index is equal or close to zero. Most features have a normal degree of variation, quantitative characters are more variable than the metric ones.

Despite the fact that all the studied species grow in similar ecological and phytocoenotic conditions, species such as *A. lasiophyllus*, *A. vulpinus* and *M. tatarica* have a rather high level of variability and plasticity, which may indicate good adaptation to any changes in the habitat. Plant individuals of *E. inderiensis* and *T. ruber* are more susceptible to external influences.

In general, the state of the populations of the studied species is alarming, since they are scarce and are characterized by a rather low regeneration associated with extremely insufficient moistening, which is detrimental to plant seedlings, especially on chalk substrates. The narrow ecological confinement and weak plasticity of the plants themselves make them extremely vulnerable to additional stress factors, for example, to the recreational impact (the Aktolagay cretaceous massif is a well-known tourist site). Apparently, more active renewal occurs only in the years favorable in terms of meteorological conditions, when in spring and early summer, there is a sufficient amount of precipitation and lower air temperatures. Due to the annual climate change towards warming, there is a fear that this will lead to significant ageing of the populations and their gradual extinction. Further monitoring of their condition is required.

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References

Agroclimatic resources of Aktobe region: scientific and applied directory (2017) Geography institute, Astana, 136 pp. [In Russian]

Ayagan B (Ed.) (2004) Aktolagay. In: Kazakhstan. National Encyclopedia. Vol. 1. Kazakh encyclopedia, Almaty, 161. [In Russian]

Borisova AG (1964) Genus 1637. Salsify – Tragopogon L. In: Flora of the USSR. Vol. 29. Russian Academy of Sciences of the USSR, Moscow, Leningrad, 8–196. [In Russian]

Chernyakovskaya EG (1939) Genus 614. Gillyflower – Matthiola. In: Flora of the USSR. Vol. 8. Russian Academy of Sciences of the USSR. Moscow. Leningrad, 285–298. [In Russian]

Darbayeva TE (2003) Flora of cretaceous massifs of North-West Kazakhstan. Diss… Dr. Biol. Sci. Thesis. Uralsk, 481 pp. [In Russian]

Darbayeva TE (2006) Partial flora of cretaceous massif of North-West Kazakhstan. Uralsk, 265 pp. [In Russian]

Fedchenko BA (1935) Genus 262. Eremurus, Shiryash – Eremurus In: Flora of the USSR. Vol. 4. Russian Academy of Sciences of the USSR, Moscow, Leningrad, 37–52. [In Russian]

Glotov NV (1998) On estimation of parameters of age structure of plant populations. In: Life of populations in heterogeneous environment. Part 1. Periodica Marie El, Yoshkar-Ola, 146–149. [In Russian]

Golovanov YM, Abramova LM (2019) Chalky highlands in Orenburg oblast, a unique habitat for rare plant species and plant communities. Arid Ecosystems 9 (2): 89–96. https://doi.org/10.1134/S2079096119020069

Golubev VN (1962) Foundations of biomorphology of herbaceous plants of the Central forest-steppe. In: Works of the Central Black Earth State Reserve named after V.V. Alekhin. Issue 7. Voronezh, 602 pp. [In Russian]

Government Decision No. 1212 of 18 November 2010. On approval of the list of geological, geomorphological, and hydrogeological objects of the state natural reserve fund of republican and international importance, the Rules of their limited economic use in specially protected natural areas, as well as the list of subsoil areas of special ecological, scientific, cultural, and other value, classified as specially protected natural areas of national importance. Information system of normative legal acts of the Republic of Kazakhstan. https://adilet.zan.kz/rus/docs/P1000001212#z6 [In Russian]

Komarov VL, Shishkin BK (Eds) (1946) Flora of the USSR. Vol. 12. Russian Academy of Sciences of the USSR, Moscow, Leningrad, 915 pp. [In Russian]

Matyashenko GV (1985) Dynamics of vegetation on cretaceous exposed of Underural plateau. Nauka, Novosibirsk, 111 pp. [In Russian]

Mirkin BM, Rosenberg GS (1978) Phytocoenology. Principles and methods. Nauka, Moscow, 212 pp. [In Russian]

Rabotnov TA (1950) Life cycle of perennial herbaceous plants in meadow prices. In: Works of the Botanical Institute of the Academy of Sciences of the USSR. Vol. 3. Geobotany, 7–204. [In Russian]

Red Data Book of the Orenburg Region: rare and endangered species of animals, plants and fungi (2019) OOO "MIR", Voronezh, 488 pp. [In Russian]

Red Data Book of the Republic of Kalmykia. Vol. 2. Rare and endangered plants and mushrooms (2014) ZAOr "NPP Jangar", Elista, 199 pp. [In Russian]

Red Data Book of the Russian Federation (plants and mushrooms) (2008) "KMK", Moscow, 855 pp. [In Russian]

Red Data Book of the Saratov Region: Mushrooms. Lichens. Plants. Animals (2006) Publishing of the Saratov region TPP, Saratov, 528 pp. [In Russian]

Red Data Book of the Stavropol Region: Rare and endangered species of plants and animals. Vol. 1. Plants (2002) Poligrafservis, Stavropol, 384 pp. [In Russian]

Prisyazhnyuk VE, Denisova LV, Muchnik EE, Nikitina SV, Zherebjateva NV (2005) Red List of specially protected rare and endangered animals and plants. Part 3.1 (Seed plants). Red Data Book Laboratory of the All-Russian Research Institute of Nature Protection, Moscow, 352 pp. [In Russian]

Smirnova OV, Zaugolnova LB, Yermakova IM, Vorontsova LI, Gatsuk LE, Yegorova VN, Zhukova LA, Kurchenko EI, Matveev AR, Mikhailova TD, Prosvirnina EA, Toropova NA, Falikov LD, Shorina NI (1976) Plant cenopopulations (basic concepts and structure). Nauka, Moscow, 217 pp. [In Russian]

The Plant List (2013) Version 1.1. URL: http://www.theplantlist.org

Uranov AA (1975) Age spectrum of phytocenopulation as a function of time and energy wave processes. Biological sciences 2: 7–34. [In Russian]

Zajcev GN (1990) Mathematical analysis of biological data. Nauka, Moscow, 184 pp. [In Russian]

Zhivotovsky LA (2001) Ontogenetic States, Effective Density, and Classification of Plant Populations. Russian Journal of Ecology 32: 1–5. https://doi.org/10.1023/A:1009536128912 [In Russian]

Zhukova LA (1995) Population life of meadow plants. RIIN "Lanar", Yoshkar-Ola, 224 pp. [In Russian]

Zlobin YuA (1989) Principles and methods of studying the cenotic populations of plants. Publishing of Kazan University, Kazan, 146 pp. [In Russian]

Zlobin YuA, Sklyar VG, Klimenko AA (2013) Populations of rare plant species: theoretical bases and methods of study. Universitetskaya kniga, Sumy, 439 pp. [In Russian]